

TELEMETRY NETWORKING USING ATM TECHNOLOGY

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ABSTRACT

The 1990's has been an era of integrating telemetry systems into networks. With the networking of telemetry systems, communications between systems is increasingly important. The telemetry system is no longer an isolated subsystem and the requirement for ubiquitous, distribution of telemetry data is also increasing. With declining DoD budgets, the cost of providing, not only, range-wide data distribution, but also, inter-range distribution is a major issue. Recent developments in commercial telecommunication data services may provide an answer to the range communications problems. In this paper, the use of Asynchronous transfer Mode (ATM) technology is examined as a means for transporting telemetry and other range data.

HIGHLIGHTS

Within the past year, ATM has become as big in the telecommunications industry¹ as it is in the banking industry with one minor difference...ATM is a broadband data transport method. The concept of Asynchronous transfer Mode, or ATM, dates back to the mid 1980's as an outgrowth of fast packet switching investigations associated with broadband integrated services digital network (B-ISDN) standards². In 1988, the CCITT adopted one packet format as a candidate for B-ISDN, calling it ATM. The ATM packet is a 53 octet cell with a 5 octet header and 48 octets of information. The concept of ATM was intended to transport a variety of services including data, video and voice. The short, fixed cell is intended to facilitate transport of high rate data in a multiplexed environment.

There is a great deal of "hype" surrounding ATM and it seems as if it is the solution to every networking problem known to man (or woman). Nevertheless, ATM technology is being implemented at an incredible rate and there are considerable advantages in

adopting the ATM technology in telemetry and other range systems. It is now clear that the future of B-ISDN is in ATM and there will be both public and private networks for data transport within the next few years. By leveraging the commercial ATM development, government applications will be able to significantly reduce capital acquisition and communications operating costs as public networks evolve.

There are, however, some stumbling blocks which must be overcome, particularly in the transmission of typical telemetry data streams. This paper addresses some of these issues based on extensive experience with telemetry data and through the development of a commercial ATM packet switch. An example of the application of ATM to the distribution of telemetry data within a range is given to demonstrate the potential of ATM to the ranges.

THE ATM NETWORK MODEL

In the ATM model, data sources are segmented into 53 octet cells and multiplexed according to the addressing information contained in the 5 octet header. An ATM network consists of a number of nodes interconnected with links, as illustrated in Figure 1, and ATM cells are transported through the network via virtual circuits, setup either by call handling services, or administratively. Two classes of services can be supported by ATM, 1) connection-oriented and 2) connection-less.

Connection-oriented services route all packets in a given transmission via the same path through the network.

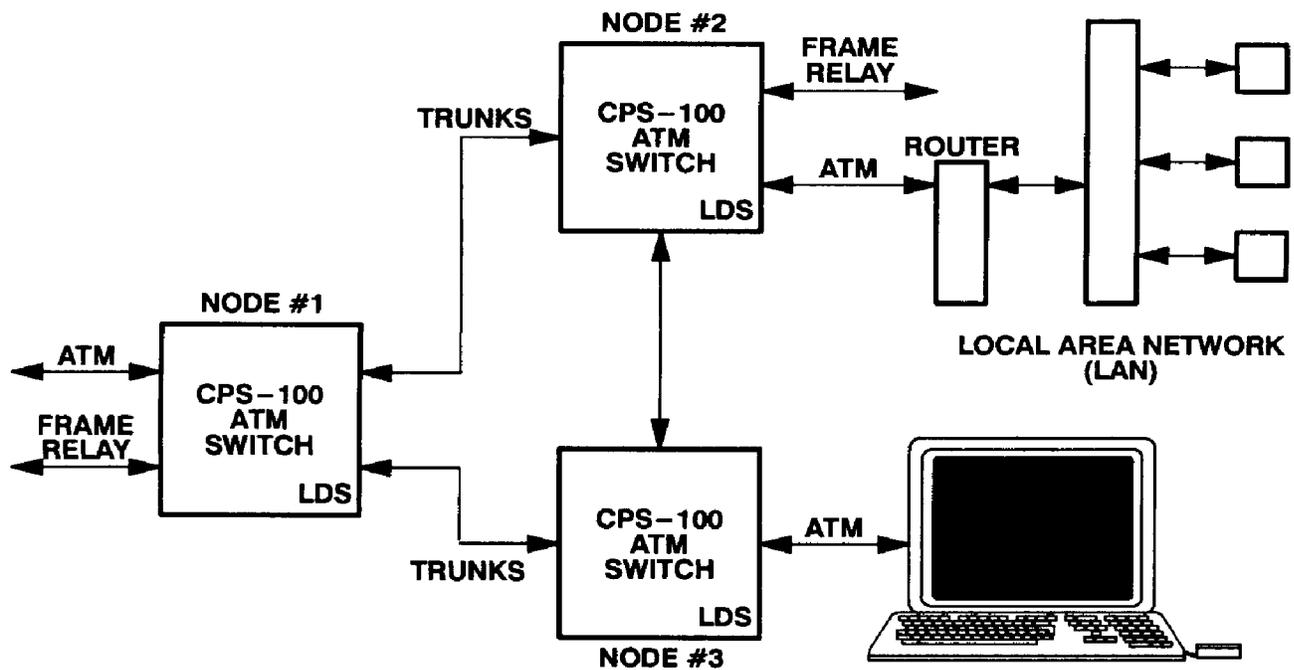


Figure 1. Three Node ATM WAN Network

One view of ATM is based on the OSI protocol stack. ATM is defined as a level 2 transport system supporting various services through level 3 adaptation layers (AAL's). Currently, ATM defines five types of services as illustrated in Figure 2. The AAL type 1 supports connection-oriented services which require constant bit rates and have specific timing and delay requirements. Telemetry data falls into this service category and requires an AAL1 stack interface for ATM transport. The AAL2

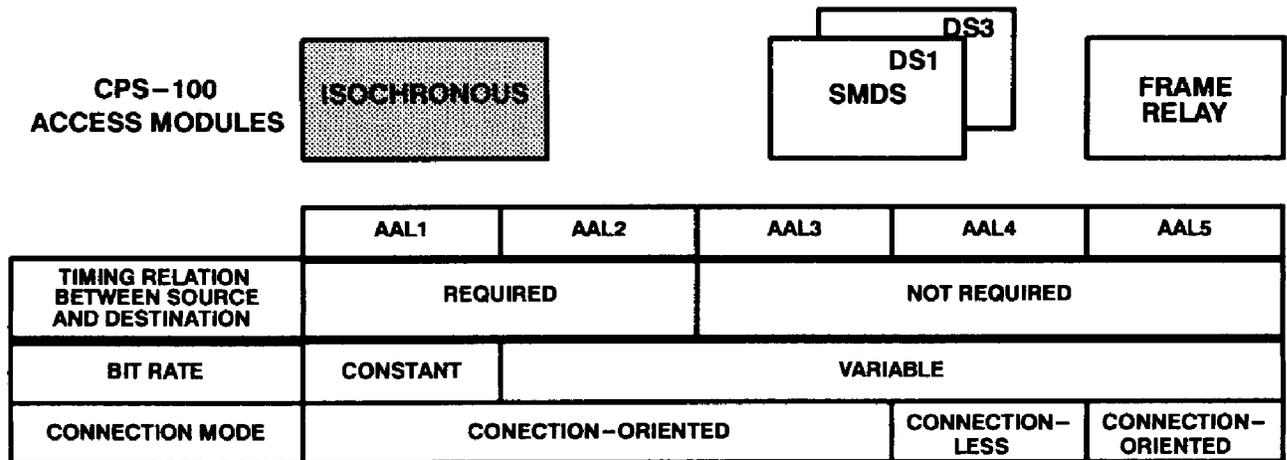


Figure 2. ATM Adaptation Layers

supports connection-oriented services with variable bit rates such as variable-rate video and some forms of data compression. AAL3/4 supports burst data and services such as Switched Multi-megabit Data Services (SMDS) which AAL5 supports connection-oriented burst data such a Frame Relay. Frame Relay and SMDS are currently offered public data services and can be used immediately for some types of range data. The Loral CPS-100 Cell Packet Switch is a commercial ATM switch which supports Frame Relay, SMDS and ATM services in one integrated platform. The experience Loral has gained in this development is being leveraged for government applications, particularly the AAL1 isochronous transport capability.

ISOCHRONOUS ATM SERVICES

The isochronous services identified as AAL1 and AAL2 have not been formally standardized in the commercial telecommunications community. For telemetry applications, the AAL1 service is required with true isochronous capability, i.e., the network must be totally transparent to a serial PCM bit stream, reproducing the stream at the output with the same average bit rate and with minimal timing jitter. For some applications, absolute delay is important, but these cases are not considered here. Apart from the CPS-100 ATM switch development, the EMR 8245 T-3 multiplexer, currently in production, provides isochronous transport of up to 8 asynchronous, PCM channels over a commercial T-4 link adding less than +/-0.2% jitter for input jitter of

up to 2%. The 8245 uses packet multiplexing technology and many of the design concepts are directly transferable to an ATM isochronous channel.

While the 8245 uses proprietary trunking formats, the ATM isochronous channel under development at Loral adheres to ATM standards so that the isochronous traffic can be freely multiplexed with other traffic streams in an ATM network. This brings a tremendous advantage to many government applications. For one, government applications can take advantage of Commercial-Off-The-Shelf (COTS) equipment. Secondly, as public ATM services are offered, the government does not have to rely on dedicated networks. Finally, the government can intermix types of data traffic over a common network. The isochronous capability will allow, for example, telemetry data streams to be intermixed with LAN traffic using Frame Relay or computer traffic using SMDS.

SOME ISSUES ASSOCIATES WITH ATM NETWORKING

It is important to note some of the assumptions surrounding the selection of the ATM concept. First, the network is assumed to have a very low bit error rate, typically in the order of 10^{-9} , or better. This was based on the premise that the broadband networks would be SONET-based, or would use other formats on optical fibre. Making the low bit error rate assumption allows the network to eliminate error checking on datagrams within the network, a major throughput limitation in lower speed packet (X.25) networks. Although provision is made in the ATM header for both error detection and correction of the header information to prevent mis-directed cells occurring due to bit errors, current standards do not attempt to correct errors, instead, discarding cells with header errors.

Secondly, the ATM network is a queuing network and cells will encounter variable delay in transport and may even be discarded with network congestion. Congestion control in ATM networks is currently under study by a variety of organizations. With very high speed networks, reactive control measures are largely ineffective and admission control policies based on predictive estimates of network congestion are under investigation.

Both the variable transport delay and the sensitivity to link bit errors are of concern in telemetry and range applications. The design of the isochronous AAL1 access module can minimize delay variation at the expense of absolute delay. When absolute delay is important, such as in command response signals, the use of a packet network, such as ATM, may not be feasible. It is also important to understand the effects of link bit errors on ATM packet transport and, perhaps, add error correction at the physical layer when the link bit error performance is inadequate.

Transmission Delay Variation

Delay in an ATM network can be broken into three major components, 1) propagation delay, 2) queuing delay and 3) processing delay.

$$Delay = T_l + T_q + T_p$$

where

T_l = link propagation delay

T_q = queuing delay

T_p = processing delay

The link propagation delay is a function of the size of the network and the speed of light, roughly 5 microseconds per mile. The second term is a function of the network load and the data rate. The last term is dependent upon the allowable jitter in an isochronous service. At low data rates and local area networks, the queuing delay typically dominates the system delay. For wide area networks and high rates, propagation delay may dominate, indeed most of the time, fixed length datagrams reside in the network³. Processing delay is important in the isochronous service. One means of reducing jitter is through the use of large buffers. For random timing delays, the mean square jitter is inversely proportional to buffering size, or equivalently, to delay. Thus delay can be traded for lower jitter and vice versa.

In most applications, delay variation is more important than absolute delay. Delay variation is, primarily, a result of queuing in the network. Loral, in conjunction with the University of Florida, has done extensive analysis and simulation of the Loral CPS-100 packet switch in network models. Delay variance is a function of traffic load with a sharp increase in variance for traffic loads in excess of 60% of capacity. Based on experimental data from the EMR 8245 T-3 multiplexer and computer simulation, an isochronous channel should be capable of reducing jitter to levels of 2%, rms, or less, in an ATM network, depending on network traffic loading.

Effects of Transmission Errors

The ATM cell has a 5 octet header which contains, among other information, the cell address used within the network for routing. One octet, the HEC, is used for an error correcting code check symbol. The original intent of the HEC was to correct header errors to prevent cells from being directed to the wrong destination in the case of an address bit error. Current standards recommend discarding the cell rather than trying to correct the header error. For the transmission of relatively short datagrams on low error links, the probability of a packet discard is quite low. For transmission of a continuous bit stream, such as telemetry, cell discard is a serious problem. Figure 3 shows the probability of at least one cell discard in a stream of "N" cells for various

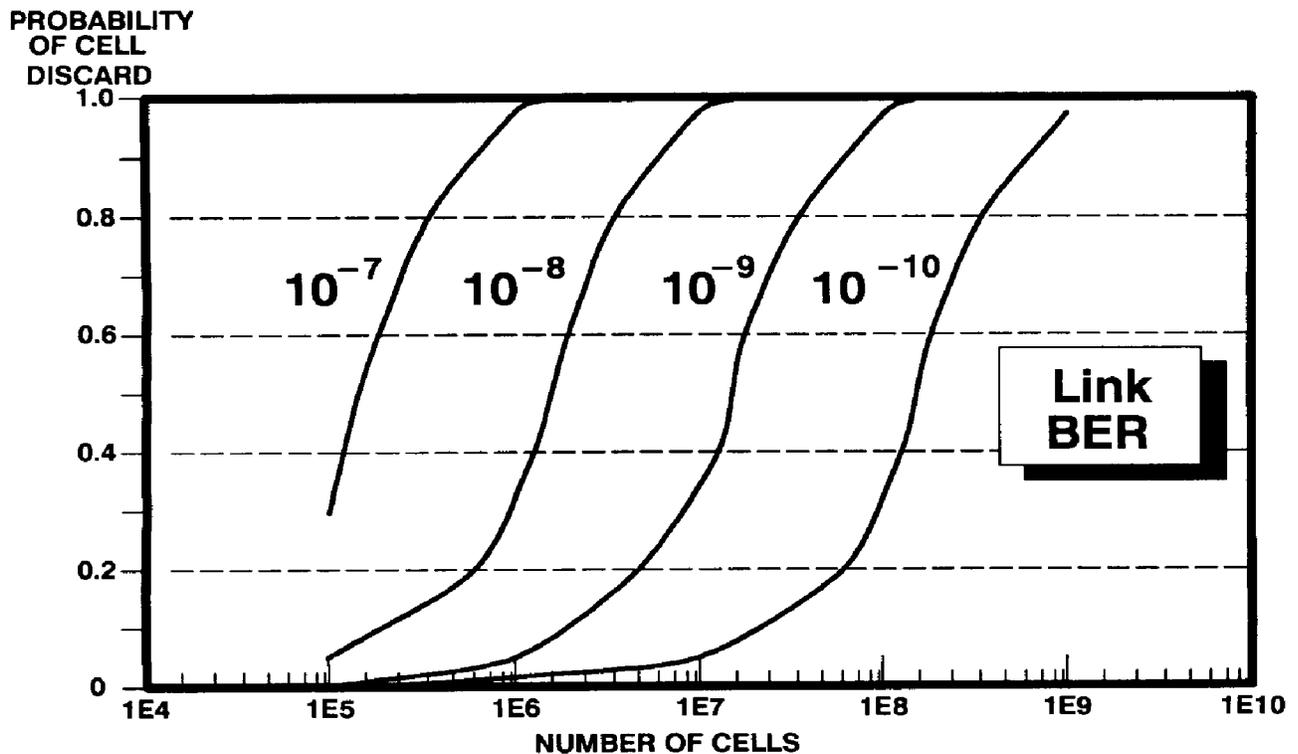


Figure 3. ATM Cell Discard Probability

link bit errors probabilities. To illustrate the transmission error problem, consider the case of a continuous, one megabit per second, telemetry stream lasting for 15 minutes. The total number of cells transmitted (one data octet is assumed to be reserved for synchronization) is:

$$\text{Number of Cells} = \frac{10^6 \text{ bps} \times 15 \text{ min} \times 60 \text{ sec per min}}{47 \text{ octets} \times 8 \text{ bits per octet}} = 2.4 \times 10^6 \text{ cells}$$

From Figure 3, the probability of at least one cell discard in the transmission is about 8% even over a typical fibre optic link with a link error probability of 10^{-9} . At 10^{-8} link error probability, the chance of a cell discard increases to nearly 65%. A cell discard would force the telemetry system at the receiving end of the link to re-synchronize, losing potentially valuable data.

There are several ways to mitigate this problem in the design of an isochronous AAL1 service. In a proprietary network, cell discarding may be inhibited for point-to-point links, or the error correcting capability of the HEC may be used to correct header errors. Alternatively, the data stream can be segmented and error correcting coding may be used to correct cell discards.

ATM RANGE CONCEPTUAL DESIGN

Current typical test range configurations appear in Figure 4. A central site serves to collect telemetry signals, 1) directly from test vehicles, 2) relayed from intermediate relay stations, or 3) piped down from remote collection sites. From this site, the telemetry data may be multiplexed, then transmitted over dedicated lines, (some fiber-optic, some not), to flight line buildings or perimeter sites which house the

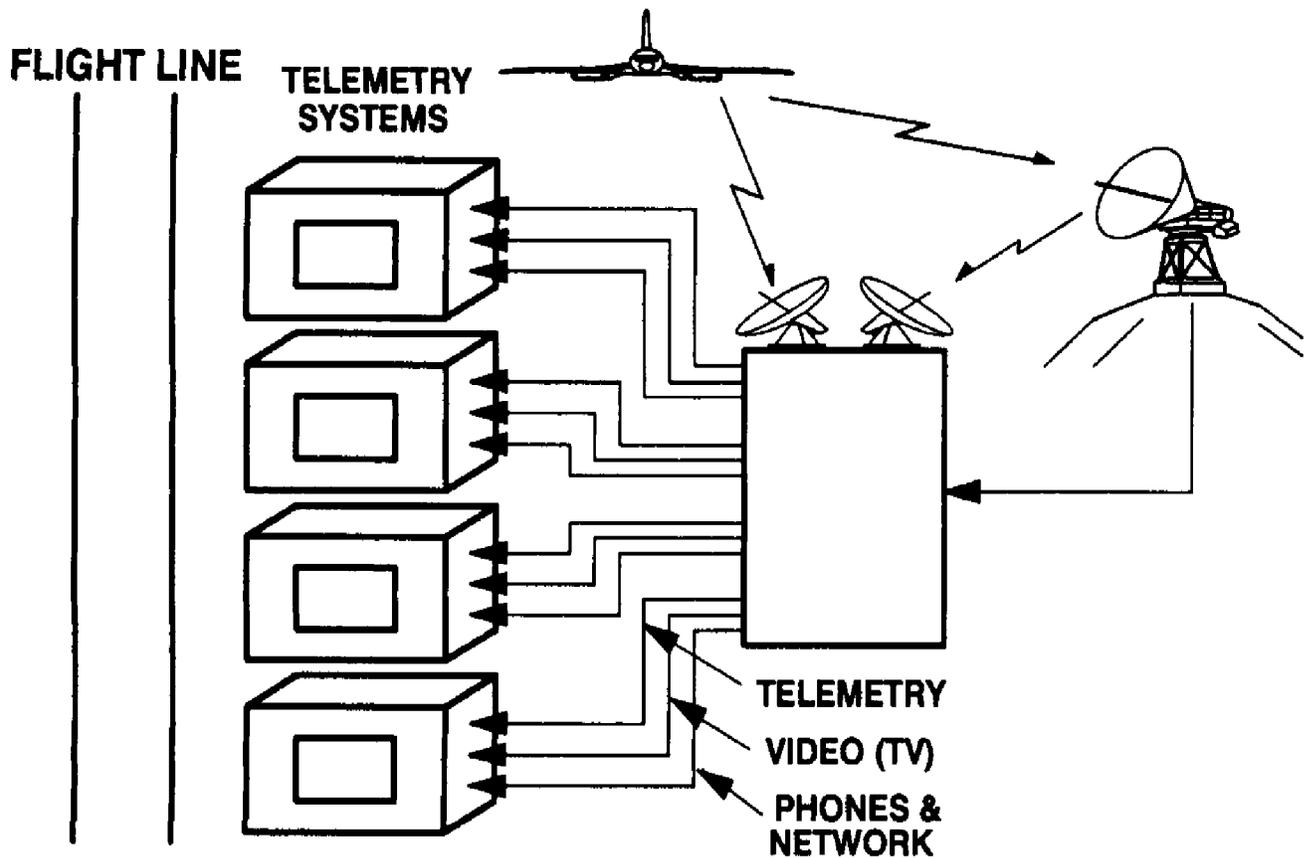


Figure 4. Test Range Configuration

telemetry systems for various projects. At certain sites this distance can be well over a mile. Here the telemetry data is demultiplexed, if necessary, and fed into the telemetry system(s). Notice that in this scenario the dedicated lines carry only telemetry data. Video, phones, and computer network traffic are each carried by their own, separate mechanism. Also notice that the sole route for telemetry data to be transferred to another test range is via the computer networking mechanism after processing by the telemetry system. This route may be through leased lines or a public phone line at a relatively slow baud rate.

By using ATM technology and commercial ATM packet switch technology, this situation could be improved upon as shown in Figure 5. Application of ATM to

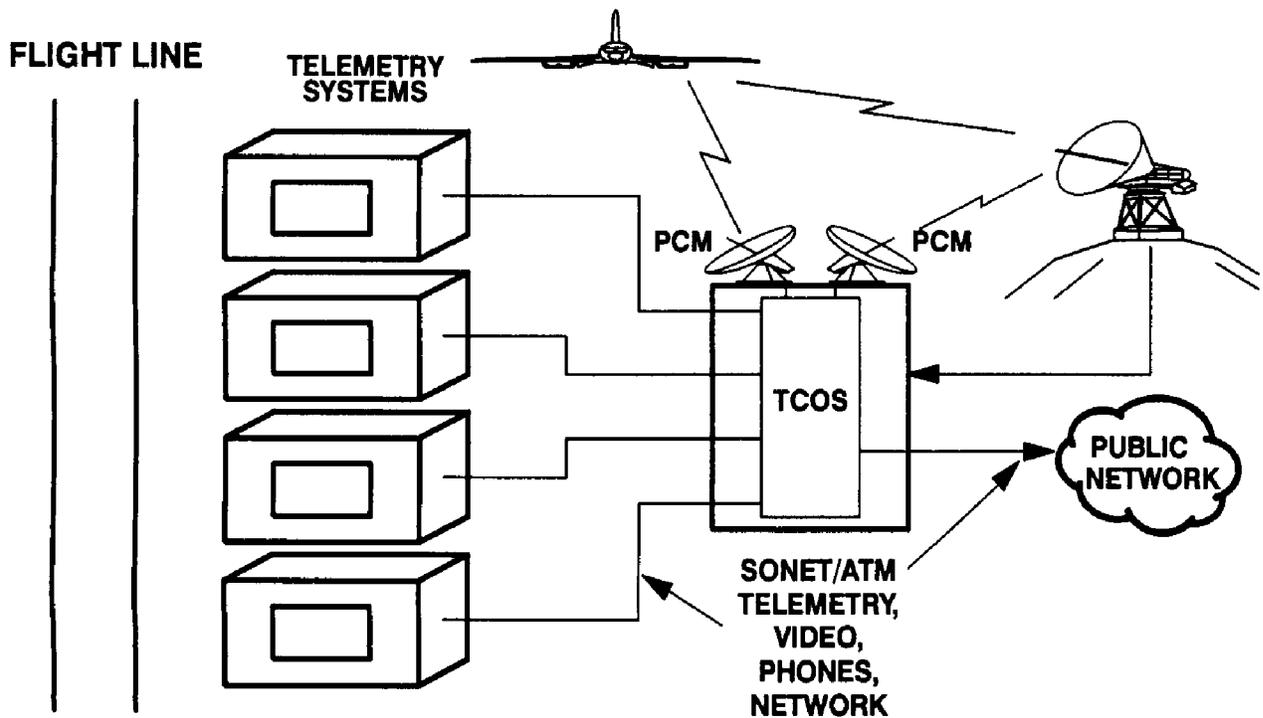


Figure 5. Test Range Configuration Improvement

telemetry data distribution provides a number of benefits to the test ranges. An ATM implementation for data distribution can provide high bandwidth throughput of multiplexed data streams over a long haul. Data streams may be telemetry data, video data, or any other measurement data normally associated with a test environment. Not only do ATM data distribution techniques provide ranges with high-speed intra-range and inter-range data transmission capabilities, but they also provide significant cost savings due to the integration of future voice, video, and networking traffic across the same medium. A conceptual design, referred to here as the Telemetry Central Office Switch (TCOS), is outlined below. The TCOS would allow for transmission of telemetry data range-wide, while providing a growth path to inter-range communications and full ATM Public Network services.

Placing a commercial ATM carrier-level Central Office Switch in the central collection site would provide a platform for the integration of ATM and telemetry data. Serial PCM telemetry data would be fed into special cards in the ATM switch, which would extract clock and data, packetize the data into groups of 48 bytes according to AAL1 adaption layer constraints, insert VP destination identifiers for each separate stream, and inject the data into the ATM switch's switching fabric. The ATM Central Office Switch would then route the data to the appropriate perimeter sites using the normal ATM routing methodology. ATM routing schemes multiplex data by default, so different telemetry streams would be multiplexed here on a cell-by-

cell basis. At this point the Central Office Switch has essentially become a Telemetry Central Office Switch (TCOS).

At the perimeter sites, an isochronous PCM module would buffer the ATM packets, demultiplex based on the VP identifiers, and recreate the serial bit streams based on the clock and data information. It's possible at this point that a fixed amount of delay may need to be inserted at the end of each minor frame to avoid jitter in the minor frame. Another look at the relationship between the TCOS and the isochronous PCM module is shown in Figure 6.

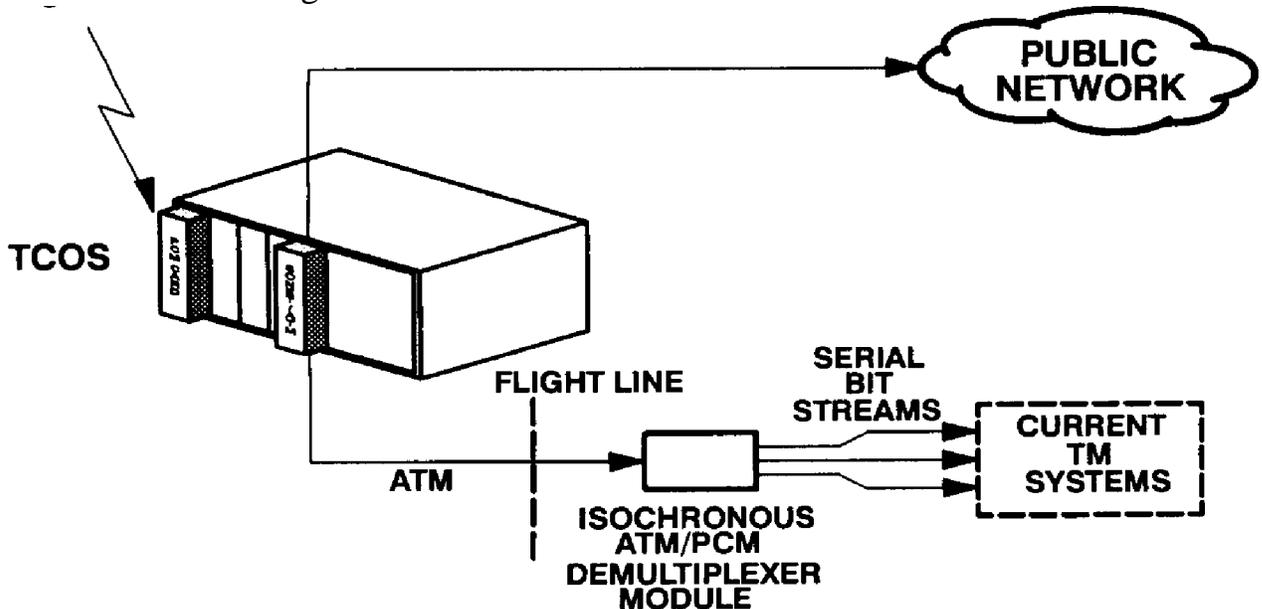


Figure 6. TCOS And The Isochronous PCM Module

The scheme of data transmission allows for multiplexing a large number of telemetry streams over a single fiber-optic transmission medium using the ATM technology. The TCOS serves as the multiplexer and the router, as well as providing an interface to the public network. Central Office Switches can provide interfaces that vary from T1 and T3 up to high speed SONET interfaces. Central Office Switches can also provide interfaces to public network Frame Relay and SMDS services. A single TCOS could multiplex telemetry data, deliver that data to the perimeter sites at T1 or T3 speeds, and simultaneously put the same real-time data into a public network ATM service for transmission to another test range across the country.

After the initial implementation of this network, the test range would be essentially ATM-ready. When the telecommunications companies are ready to deliver ATM/SONET services to the ranges via the public networks, (or private networks), the configuration could be modified as presented in Figure 7.

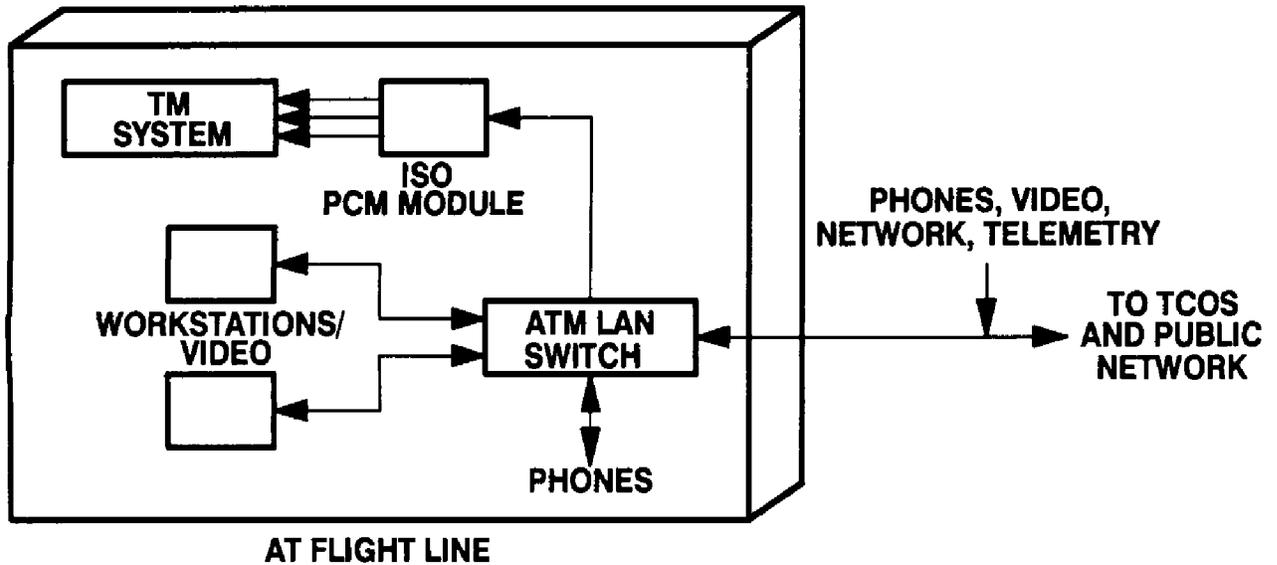


Figure 7. ATM/SONET Services Modifications

The TCOS would be by nature a Central Office Switch, so the Customer Premises Switch required for a facility the size of a test range would already be in place. The addition of an ATM SONET interface into the TCOS could provide the interface to the Public Network. By placing a LAN ATM switch in front of the isochronous PCM module and installing the appropriate ATM interface devices, all voice (phones), video (TV), network (computer), and telemetry data could be multiplexed onto the same line(s) as the telemetry data. The isochronous PCM module would be simply another node on the ATM network. This could provide a significant cost savings for the test ranges.

Figure 8 is a look at the final phase of this scenario. By installing TCOS and isochronous PCM modules in facilities across the country, end-to-end real-time data

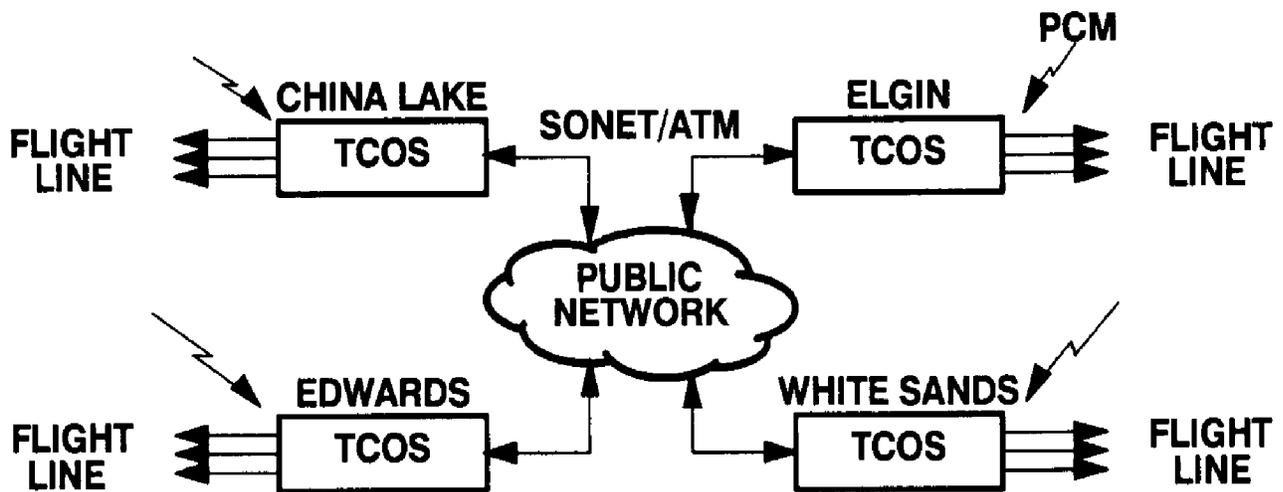


Figure 8. Final Phase Scenario

distribution could be achieved using ATM technology and high-speed SONET transmission lines. This could be either over the Public Network or over a private network of leased lines. Either way, telemetry data acquired at a test range in California could be acquired, archived, analyzed, and displayed in real time at a test range in Florida. This data could easily be integrated and correlated with video and voice data integrated into the same ATM network.

CONCLUSION

ATM technology holds great promise as a transport means for telemetry and other range data. The development of an isochronous channel is required for telemetry data streams and, while there are technical problems, the use of error correcting coding and other methods offer ways of solving these problems. An example of the use of ATM in the context of a test range illustrates the potential of the technology. Government use of ATM technology can take advantage of many commercial developments, both saving money, and increasing data transport capability.

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